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VISUAL AND AUDITORY EFFICIENCY AND ITS RELATIONSHIP TO READING IN CHILDREN.

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THE RELATIONSHIPS BETWEEN AUDITORY AND VISUAL FUNCTIONING AND READING ACHIEVEMENT WERE EXPLORED. AN ADDITIONAL OBJECTIVE WAS TO INVESTIGATE THE INFLUENCE OF DEVELOPMENTAL FACTORS ON THESE VARIABLES. A WIDE RANGE OF AUDITORY AND VISUAL SKILLS WAS SAMPLED IN POOR AND NORMAL READERS AT THREE DIFFERENT GRADE LEVELS (FIRST, THIRD, AND FIFTH). DATA OBTAINED UNDER EXPERIMENTAL CONDITIONS INCLUDED--(1) REACTION TIME TO LIGHTS AND TONES, PRESENTED SEQUENTIALLY, (2) VIGILANCE PERFORMANCE UNDER CONDITIONS OF AUDITORY, VISUAL, AND COMBINED AUDITORY-VISUAL PRESENTATION, (3) AUDITORY AND VISUAL DISCRIMINATION SKILLS WITH MEANINGFUL AND NONMEANINGFUL MATERIAL, (4) AUDITORY AND VISUAL SPAN OF WORDS AND DIGITS, (5) AUDITORY AND VISUAL SERIAL LEARNING OF WORDS, AND (6) CONCEPT FORMATION SKILLS. RESULTS OF THIS STUDY INDICATED THAT READING MAY BE ADVERSELY AFFECTED BY ANY ONE OF THE PSYCHOLOGICAL PROCESSES OF DISCRIMINATION, MEMORY, LEARNING, AND CONCEPTION. IT WAS ALSO DETERMINED THAT DIFFICULTIES IN ATTENDING, MEMORIZING, OR LEARNING WITHIN PARTICULAR SENSORY MODES ARE RELATED TO READING RETARDATION. IT APPEARED THAT THE READING LEVELS OF YOUNGER CHILDREN WERE AFFECTED BY DIFFICULTIES IN DISCRIMINATION. (WB)

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Visual and Auditory Efficiency and its Relationship to Reading in Children

Cooperative Research Project No. 1099

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I. Statement of the Problem

One of the most serious problems facing educators today is the high percentage of children who are retarded in reading. This issue has recently been attracting a great deal of attention and many rehabilitative efforts are currently being conducted in the schools. Although remediation is obviously necessary, a more comprehensive approach to the reduction of reading disabilities requires the delineation of causal variables. Under optimal conditions, such an approach would lead to early diagnosis of learning problems and thereby would prevent both the failure experiences and the negative attitudes towards education many poor readers subsequently develop.

Towards this end, the current investigation attempted to explore certain aspects of children's modality functioning which appear to underlie reading behavior.

Reading is an enormously complex process which encompasses numerous sensory, motoric, conceptual and communication skills. The teaching of reading is, in fact, predicated on the possession of minimal levels of certain of these skills. In early reading instruction, for example, the child is required to learn to associate a specific oral-language response (the teacher's voice) to a novel visual cue (a printed word). This process presupposes that the child is capable of attending to, discriminating, recognizing, and remembering both auditory and visual stimuli. The assumption is typically made that the beginning learner is, in fact, equally proficient with regard to both these channels of communication. This need not be the case, however. Difficulties might arise with respect to any one of a number of such skills, and may be more pronounced in one modality than another. Furthermore, it is conceivable that the child may

be perfectly capable of responding to and retaining auditory or visual information when presented alone, but may experience difficulty when both kinds are presented together.

The present research was directed towards the gathering of information about interrelationships among such visual and auditory functions and reading. If inadequate abilities in these underlying skills could be found to exist in poor readers, such information could have many pragmatic implications. It might be possible, for example, to avoid reading difficulties in some children by administering training in these auditory and visual skills at an early stage.

The notion that defective auditory and/or visual functioning may play a role in producing reading retardation is certainly not a new one. In recent years, in fact, there would appear to be an increased interest in studying the perceptual behavior of reading retarded children. An outstanding difficulty with most of the research in this area, however, is that it has tended to be restricted in scope. Studies have typically focused on only one specific auditory or visual skill (usually acuity) with one particular age group. As a result of this piecemeal approach, insufficient attention has been devoted to two issues of major theoretical importance: (a) the relationships between audition and vision in various skills, and (b) the developmental aspects of such modality functioning.

Because of the lack of empirical evidence in these areas, a host of questions of obvious importance to the educator remain unanswered. With regard to modality interrelationships, for example, the question can be raised as to whether auditory and visual materials evoke equivalent performance in all subskills underlying reading or whether some more complex interactions exist between skill and modality. With respect to developmental comparisons, the issue could be raised of whether certain

skill deficiencies might persist in reading retardates whereas others might diminish at some point, irrespective of training. Additionally, one might ask if the relative contributions of certain skills to reading is the same at all age levels or whether they differ.

Answers to such questions are currently unavailable on the basis of the existing literature. A comprehensive theory concerning perceptual development and its relationship to reading achievement is equally unavailable at the present time. As a first step, however, basic information is required concerning the modality functioning of children.

The present report represents an attempt to obtain such data on a population which typically has an extremely high incidence of reading disorders associated with it, namely, Negro lower-class boys. The measurement and evaluation reported herein included a wide variety of perceptual and conceptual tasks which were administered to children of differing reading ability at three age levels. In this way, the interrelationships enumerated above (i.e., between skill, modality, age and reading level) could be systematically examined. It was anticipated that such information could be profitably used by educators to assess patterns of retardation more accurately, and to structure remedial work accordingly.

II. Objectives

The research reported herein was designed to explore the relationships between auditory and visual functioning and reading achievement. An additional objective of the present design was to investigate the influence of developmental factors on these variables.

Towards this end, a wide range of auditory and visual skills was sampled in poor and normal readers at three different age levels. The

design permitted comparison of these children on tasks requiring combined auditory-visual functioning as well as comparison of individual communication channels.

In addition to variation of the stimulus modality, tasks were also varied according to complexity. Reading is a complex skill involving attentional, perceptual, learning and conceptual processes. An attempt was made in the present study to sample some of these component skills. More specifically, the following kinds of data were obtained from good and poor readers:

(a) Reaction-time to lights and tones presented sequentially.

(b) Vigilance performance under conditions of auditory, visual, and combined auditory-visual presentation.

(c) Auditory and visual discrimination skills with meaningful and nonmeaningful material.

(d) Auditory and visual memory span of words and digits.

(e) Auditory and visual serial learning of words.

(f) Concept formation skills.

It was hoped that the results of this project would contribute some basic and needed information concerning the perceptual and conceptual patterns of children, which are related to success in reading. Pragmatically, such data might be useful in the early diagnosis of reading problems and the construction of more effective remedial techniques

III. Related Research

There are virtually no studies which have employed a multivariate approach in investigating both auditory and visual skills with the same population. For this reason, the research relevant to the present project will be discussed according to the individual measures employed.

A. Reaction Times under Conditions of Auditory-Visual Presentation

It is not within the realm of the present project to consider the vast literature on simple auditory and visual reaction times. Of interest, however, are investigations of reaction-time performance on tasks requiring rapid attentional shifts between the auditory and visual modalities.

In an early study employing adults, Mowrer (1941) found that reaction times increase when stimuli from a different modality are introduced into a series of stimuli in a single modality. Thus, shifting attention between modalities appears to be a harder task than attending to either one alone.

The amount of latency increase associated with shifts in stimulus modality has been shown to be differentially related to particular population variables. Sutton (1959), for example, demonstrated that the behavior of schizophrenic patients on shifting tasks differed from that of normal controls. Benton (1962) has obtained similar results with neurological patients.

In the only study investigating this phenomenon in children, Raab, Deutsch and Freedman (1960) found a relationship between modality shifting efficiency and reading achievement. The Raab study, however, was restricted to a sample of sixth-grade children.

The present study attempted to replicate Raab's findings and to investigate the developmental aspects of the relationship. If perceptual difficulties arising from modality shifting do, indeed, impede reading progress, they should be present not only at the upper elementary school grades, but should also be observable in young children, who have not yet received reading instruction.

B. Vigilance Performance

A vigilance situation has been operationally defined as one in which a subject must respond to a sporadically presented stimulus (McCormack, 1960). This particular kind of task has also been called "monitoring" and "watch-keeping". Although there are some variations in the experimental paradigm, what is typically required of the subject is a period of sustained attention. What is measured in such situations is the subject's efficiency in detecting signals, usually of a visual nature. Generally speaking, vigilance tasks do not involve difficult discriminations. The signals to be detected and responded to are easily discriminable.

The bulk of research efforts in this area has been devoted to a consideration of the effects of particular environmental conditions on adult vigilance performance. Such factors as degree of task duration, length of inter-stimulus intervals and number of rest intervals have been extensively investigated in adults (e.g., Kennedy and Travis, 1947; McCormack, 1958; McCormack, 1960). The emphasis has been primarily upon generalizability to human engineering problems.

Although the kind of sustained attention required on vigilance tasks would seem to bear some similarity to the perceptual requirements of the reading situation, there are no studies which have investigated the relationship between reading and vigilance performance.

Several recent studies have attempted to employ vigilance performance as a diagnostic indicator of brain damage. Rosvold et al. (1956) have devised an adaptation of the vigilance technique which they call the Continuous Performance Test. This test was initially found to differentiate between brain-damaged and normal adults. In a second

study, Mirsky et al. (1960) showed that patients with cortical abnormalities showed no dificit in vigilance whereas those with subcortical involvement showed poor vigilance performance. These investigators also found that significant impairment in vigilance occurs in subjects who have taken depressant drugs or who have been deprived of sleep for long periods of time. In a recent investigation, Schein (1962) found the reliability of the Continuous Performance Test to be very high.

The present study explored vigilance performance of poor and good readers by employing an adaptation of the Continuous Performance Test for use with children. An attempt was also made to extend the investigation of vigilance behavior to other modalities besides the visual. Thus, an auditory form and a combined auditory-visual version were used in the current project, in addition to the more standard visual one.

C. Auditory and Visual Discrimination Skills

Even the most cursory examination of early reading instruction would reveal that both auditory and visual discrimination are involved. On the one hand, the child must be capable of developing the ability to discriminate among initially meaningless and highly similar visual forms. On the other hand, the teacher typically expects that the first-grade child can differentiate between the speech sounds which will come to be associated with the written symbols. Thus, it would appear that any deficit in either visual or auditory discrimination would contribute to reading difficulty.

Despite the seemingly obvious nature of the above statement, the literature to date appears to be somewhat contradictory concerning the role that auditory and visual discrimination skills play in producing reading retardation (Johnson, 1957).

One difficulty is that although a great deal of research has been done on visual acuity (e.g., Robinson, 1946; Goins, 1958), there are not many investigations of visual discrimination skills. It should be noted at the outset that visual discrimination and visual acuity are not perfectly correlated. It is quite conceivable that a child with ostensibly good eyesight might still have problems with discrimination since the ability to detect differences and similarities in the visual stimuli is not solely a function of ocular functioning, but may involve attentional and conceptual factors as well.

The reports of several investigators are somewhat ambiguous regarding the role of visual discrimination in reading. Gates (1922), for example, found that backward readers were not inferior to normal readers in perceiving small differences in drawings and numbers, although they were decidedly inferior in detecting small differences between word pairs. These results were replicated with middle and upper elementary school children (Gates, 1926; Riley, 1929; Phelan, 1940). Two more recent studies, however, by Galifrent-Granjon (1951) and Kendall (1948) have failed to obtain any relationship between reading ability and differentiation of visual forms.

In a recent discussion, Vernon (1957) suggests that the deficit may be more pronounced in younger children. The present study examined this possibility. An attempt was also made in the current investigation to increase control over the presentation of visual stimuli through the use of a tachistoscope. The earlier studies cited employed paper and pencil techniques in which exposure time was not controlled.

The relationship between auditory discrimination skills and reading achievement appear to be somewhat clearer. Positive relationships

between capacity to discriminate simple and complex sounds and reading ability in middle and upper elementary school children have been reported by a number of investigators (e.g., Bond, 1934; Wolfe, 1941; Wheeler and Wheeler, 1954; Wepman, 1960). It should be noted that even here there are some dissenters. Reynolds (1953) obtained negative findings.

As was the case with the work on visual discrimination, the developmental aspects of auditory discrimination skills have not been fully investigated. Another difficulty with the body of research cited above is that the presentation of the auditory stimuli was not adequately controlled. Where discrimination of words was involved, the experimenter typically read the words aloud to the subject. Thus, the pronunciation was not held constant from subject to subject. An additional difficulty with this approach is that the subject could obtain additional visual cues by observing the lip movements of the experimenter. In the present study, these problems were circumvented by employing taped presentation of auditory stimuli.

The question of the relative efficiency of auditory as compared with visual discrimination is currently unanswerable as there are no studies which have investigated auditory and discrimination skills in the same group of children. The present study attempted to provide some information on this issue. A shortened and taped form of the Wepman Auditory Discrimination Test was employed, together with a visual counterpart using English words. In addition, a visual and auditory discrimination test composed of nonmeaningful materials was employed to assess whether anticipated developmental gains in discrimination were related to general improvement in perceptual ability, or merely to a greater familiarity with English words.

D. The Influence of Visual vs. Auditory Stimuli on Memory and Learning Efficiency

Investigators have long been interested in comparing the eye and the ear in the areas of memory and learning. The earliest studies date back to 1894 and were, for the most part, concerned with visual and auditory memory in adults.

It is extremely difficult to draw any conclusions from this body of research. evidence from several studies revealed that the visual modality was superior for memory of colors, nonsense syllables and words (e.g., Munsterberg and Bigham, 1894; Whitehead, 1896; O'Brien, 1921; Koch, 1930; Krawiec, 1946). Other investigators, however, found that auditory presentation was superior for memory and retention of nonsense syllables, words, digits and prose (e.g., Henmon, 1912; Cantril and Allport, 1935; Elliot, 1936). Thus, it is clear that no general agreement exists as to whether auditory or visual presentation is superior with adults.

In a more recent discussion of this area, Henneman (1952) suggested that the general question of whether the auditory or visual channel was more efficient was meaningless without an accompanying consideration of both the type of task and the kind of subjects.

The correctness of Henneman's observation becomes immediately apparent when the studies employing children are contrasted with those using adults as subjects. The few studies investigating children have all indicated that auditory presentation is superior at the elementary grade levels (Kirkpatrick, 1894; Russell, 1938; Worcester, 1925; Young, 1936). In a more recent study which varied the level of reading achievement, Friedman (1959) concluded that the advantage of auditory over visual presentation was even more pronounced for fifth-grade retarded readers than for normal readers.

It might appear, then as if the issue has been resolved with children. A most serious limitation of the previously cited studies, however, is that in all of them, the visual stimuli employed were printed words. These earlier results, therefore, might have been explained more parsimoniously as having been related to unfamiliarity with the reading material rather than to any intrinsic inferiority of visual compared with auditory learning. Thus, the question of which mode of presentation is superior in young children's learning remains an open one. The present investigation attempted to control for the familiarity variable by employing pictures of common objects rather than printed nouns.

IV. Procedure

A. Subjects

Subjects were chosen from the first, third, and fifth grade classes of two elementary schools in the Harlem area of New York City. The Gates Advanced Primary Reading Test was administered on a group basis to all male pupils in the third and fifth grades in both schools at the beginning of the school year (total N = 385). In order to assess potential reading ability on the first-grade level, the Reading Prognosis Test of the Institute for Developmental Studies was administered to all first-grade males at the two schools at the beginning of the year (total N = 178). This Reading Prognosis Test (RPT) has been described in detail elsewhere (Weiner and Feldmann, 1963). Its reliability and predictive validity on a similar sample appeared sufficiently high (r = .82) to warrant its use as a prognostic indicator. A copy of this test is presented in Appendix A.

Frequency distributions of reading scores were obtained for each grade level, and the final sample was selected from the upper and lower

30% of these scores. The children whose scores fell in these categories constitute the "high" and "low" readers. The resultant sample numbered 168 children. There were 28 children at each reading and grade level, (i.e., first grade low, first grade high, etc.). The mean Reading Prognosis and Gates APR score for each grade are presented in Table 1.

Table 1

Mean Reading Prognosis and Gates APR Scores
(in grade level) of Sample Children
(N = 28 in each group)

	Reading Group	
Grade	Low	High
1st	29.8	83.2
3rd	2.2	3.9
5th	2.8	5.0

In addition to reading tests, Lorge-Thorndike Intelligence Tests were administered at the beginning of the school year to all sample children. Also, information relevant to the socio-economic status of 75% of the children was obtained from mail questionnaires sent to the parents. The results indicate that most of the children in the sample come from families where the parents work at unskilled factory jobs and have received little education beyond elementary school.

It should be noted that the final group of 168 children does not constitute a completely random sample. Children were selected for the final sample if, in addition to the reading scores, they met the following criteria:

(a) Ss were Negro and male (approximately 95% of the children in the two schools were Negro).

(b) English was the dominant language spoken at home.

(c) Lorge-Thorndike I.Q. was 70 or above.

(d) No severe emotional, visual or auditory problems were noted on the school record cards.

Thirty-five children with reading scores in the upper and lower 30% of the distribution were eliminated because they did not meet one or several of the above criteria. The final sample of 168 was, however, selected randomly from the remaining pool of 300 children.

Because of both time limitations and the undesirability of repeatedly testing the same children, not all Ss received all techniques. Instead, children were randomly selected from the sample of 168 to receive one or two measures.

B. Techniques Employed

1. Bimodal Reaction Time Apparatus

This apparatus, previously described in detail by Sutton (1959), is capable of automatically presenting four separate stimuli: a red light, a green light, a high tone of 1200 cycles per second and a low tone of 400 cycles per second. The specific design used was somewhat modified for greater portability. In the present study, S's task was to lift his finger from a button every time a stimulus was perceived. Reaction time to each stimulus was automatically recorded. The stimulus program was designed so as to appear random to Ss. However, each stimulus was preceded by every other one an equal number of times. The interval between stimuli was varied randomly, lasting for either 1.5, 2.0 or 3.0 seconds. There was a one-minute delay at the end of each block of 33 trials. The program used is presented in Appendix B.

A group of 48 Ss was chosen from the total pool of 168. There was an equal number of children from each grade and reading level. All Ss were tested individually in the school. Upon entering the experimental room, S was seated in front of the apparatus and instructed as follows: "We're going to play a game with lights and sounds. See this window. Well, every now and then you will see some lights here; a red light or a green light. Other times you will hear some sounds, a high sound or a low sound. Now, I would like you to put your finger down on this button. Every time you see a light or hear a sound, pick up your finger as fast as you can. Then put your finger right down again and wait for another light or sound. When another one comes, pick up your finger again as fast as you can. Then put it right down and wait for another light or sound. When another one comes, pick up your finger again as fast as you can. Then put it right down again and wait for another."

The presentation of the stimuli automatically terminated if S did not repress the button. When this occurred, S was told to press the button again which began the sequence. Each S received 198 trials.

2. Continuous Performance Test

In this technique, an adaptation of a test described by Rosvold et al. (1956), colors were employed as stimuli. There were three forms of the test: visual, auditory, and combined auditory-visual. In the visual version, the stimuli were dots of different colors on a memory drum. S was exposed to one stimulus per second. His task was to press a button as soon as he saw the color red. In the auditory form, the stimuli were tape-recorded names of colors. Again, S was exposed to one stimulus per second. Analogously, S was instructed to press a button as soon as he heard the word "red". On each version of the tasks, 80 "red"

stimuli were randomly interspersed among a total of 560 stimuli. S's performance was automatically recorded on tape and reaction times to the correct stimuli were obtained from those tapes. In order to be correct, S had to press the button within a period of 100 milliseconds to one second after the stimulus presentation.

A total of 48 Ss were tested on the combination form of the Continuous Performance Test. In this technique 280 auditory and 280 visual stimuli were randomly interspersed. There were 40 red visual stimuli and 40 auditory "reds". S was instructed to press the button as soon as he either saw the color red or heard the word "red".

Due to equipment problems on the single auditory and visual versions of the test, the initial protocols obtained could not be used. The equipment was rebuilt and Ss were tested the following year on these techniques. Thus the results are not directly comparable to the combination form since the auditory and visual CPT's were administered to second, fourth, and sixth grade Ss. A total of 66 Ss received the single auditory and visual versions, counterbalanced for order of administration.

3. Modality Preference Test

No previous work could be found on modality preferences in children. Accordingly a technique was devised by the Institute for Developmental Studies which attempted to measure such preferences.

The apparatus consisted of two rectangular boxes 75 inches long and 15 inches high. These were set on tables and arranged at right angles to each other. Each box was divided and had five sections, two of which contained auditory and two of which contained visual stimuli. In addition, each stimulus panel contained a red button. This button both

activated the stimulus and deflected a stylus on an attached impulse recorder. The four visual stimuli employed were: white lights, colored lights, a picture and a moving spiral. The auditory stimuli were: a buzzer, a bell, a train whistle, and a music box. A diagram of the apparatus, depicting the arrangement of the stimuli is present in Figure 1.

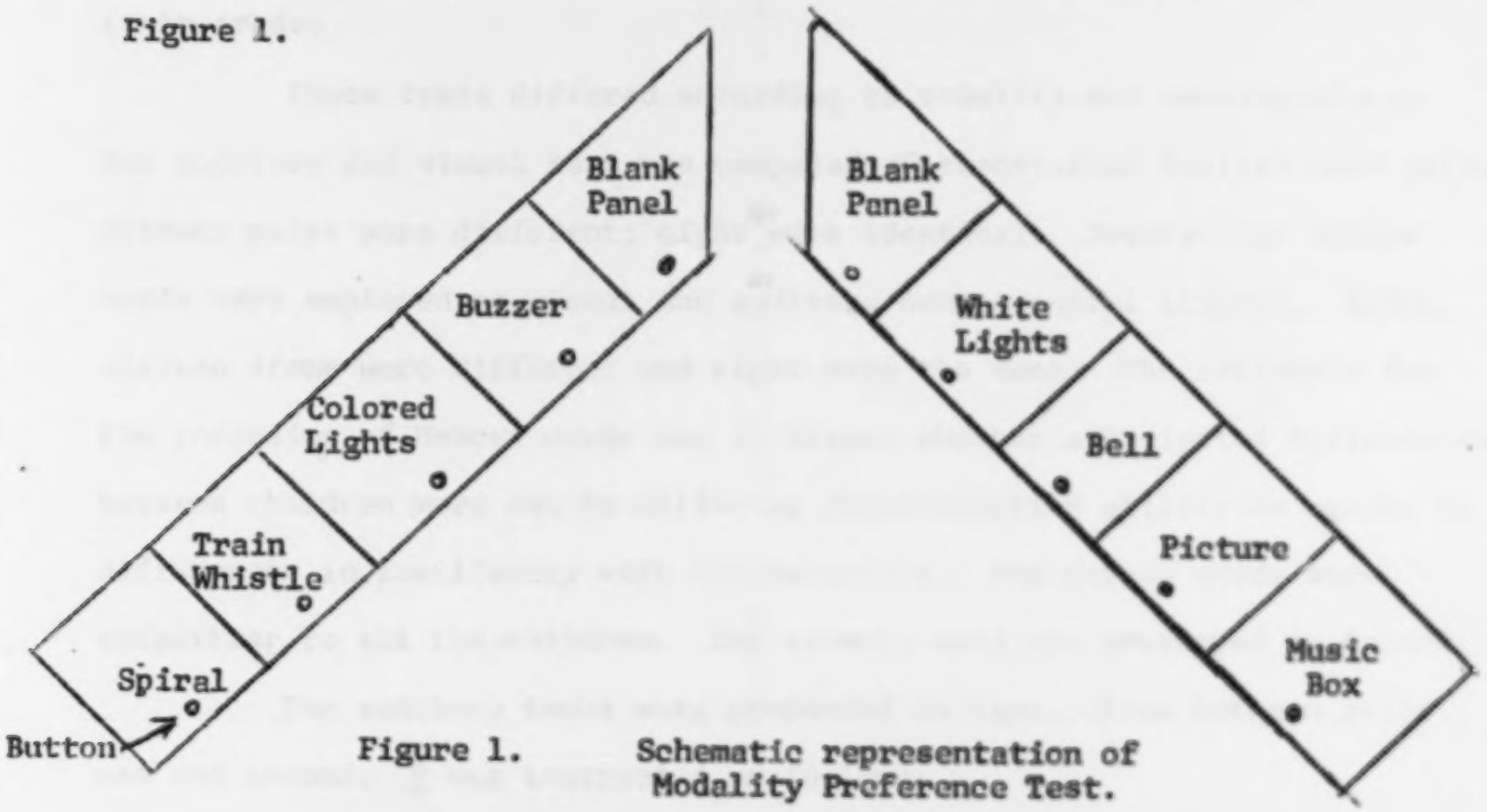

Figure 1. Schematic representation of Modality Preference Test.

Upon entering the experimental room each S was instructed as follows:

"Do you see these boxes with the red buttons? When you press the buttons you will see and hear different things. Let me show you what to do. (E presses each button for 2 seconds in consecutive order.) See? Every button makes something different happen. Now I'm going to let you press the buttons. When I say "go" you can press any of these for as long as you like until I tell you to stop."

Each S was permitted to play the game for four minutes. Forty-eight Ss received this task. Performance was recorded by means of

two impulse recorders on waxed tape. The number and the duration of presses for each stimulus were obtained from the records.

4. Discrimination Tasks

Four discrimination tests were administered to seventy-two Ss in the second year of testing, i.e., Ss were in the second, fourth, and sixth grades.

These tests differed according to modality and meaningfulness. One auditory and visual test was composed of twenty-four English word pairs. Sixteen pairs were different; eight were identical. Twenty-four Hebrew words were employed as visual and auditory nonmeaningful stimuli. Again, sixteen items were different and eight were the same. The rationale for the inclusion of Hebrew words was to assess whether anticipated differences between children were due to differing discrimination ability or merely to differences in familiarity with the materials. The Hebrew words were unfamiliar to all the children. The stimuli used are presented in Appendix

The auditory tasks were presented on tape. Time between pairs was one second. S was instructed as follows:

"Some words will be read to you--two words at a time. I want you to tell me whether you hear the same word twice or two different words. Remember if the two words are exactly the same, you say "yes" or "same". If they are not exactly the same, you say "no" or "different".

The visual stimuli were presented on slides. A tachistoscopic shutter was used and the word pairs were exposed for a one-second duration. Instructions analogous to those of the auditory task were employed.

Each S was seen twice and given an auditory and visual discrimination test at each sitting. The order was counterbalanced across Ss.

5. Memory Span

Both auditory and visual memory span were tested using digits and verbal material.

With the auditory test, S was instructed as follows:

"I'm going to say some numbers (or words) and when I'm through I want you to tell me just what you heard."

For the visual tests, the instructions were:

"I'm going to show you some numbers (or pictures), and when I'm through I want you to tell me just what you saw."

The digit span was administered both auditorially and visually. The items ranged from two to eight digits, and testing was discontinued if S missed two consecutive items at any level.

The stimuli employed to test S's memory span for words are presented in Appendix D. The procedure employed differed from the Digit Span Test in that eight items (either pictures or words) were presented either visually or auditorially and S's score was the number of items S could repeat after one trial.

There were 72 Ss who received these tests.

6. Serial Learning Tasks

Serial learning was measured by the number of correct responses made to fifteen trials of the above mentioned words and pictures. In addition to the single auditory and single visual presentation, a combined test was also administered to 48 Ss. The combined version consisted of four words and four pictures employed in alternating sequence. (See Appendix D for stimuli.) S was instructed to repeat everything he saw and heard. The particular items which were presented visually or auditorially were counterbalanced across Ss.

Testing was discontinued after one perfect repetition of the eight items or at the end of fifteen trials. Pretesting revealed that the task was too difficult for first grade Ss if the correct order was required in the repetition. Accordingly, the order of repeated items was disregarded in the analysis although E always presented the stimuli in the same order.

7. Concept Formation Test

Although not originally included in the basic design of this project, it was deemed useful to obtain information on children's conceptual performance. Accordingly, a new test was designed by Katz in an attempt to measure the nonverbal concept formation ability of good and poor readers.

Some recent studies have pointed up what appears to be a rather fruitful approach to this area in terms of information theory (Bourne and Restle, 1959). Archer and Bourne (1955), for example, have shown that the difficulty of items on concept formation tasks for adults is a function of the number of irrelevant cues.

An adaption of Archer and Bourne's technique was employed in order to assess whether difficulty in children's concept formation could also be related to amount of irrelevant information and additionally to examine whether good readers differed from poor readers in the ability to conceptualize. Insofar as reading is a conceptual activity involving the learning of symbols, it would be expected that differences in conceptual ability would affect reading performance.

The stimulus items on the test were geometric figures which differed according to the four attributes of form, color, size, and number. Three dimensions of each attribute were used, i.e.,

Form: circle, square, equilateral triangle

Color: red, blue, yellow

Size: small, medium, large

Number: one, two or three figures

The concepts involved varied in three major ways: (1) the attribute relevant to solution (form, color, size, or number); (2) the number of irrelevant cues (one, two or three); and (3) the number of relevant cues (one or two). A relevant cue was one which could be used to form the concept. An irrelevant cue was one which was varied in the examples of the concept shown to the children.

The test contained five conceptual categories, represented by four items. More specifically, these categories can be described as follows:

I. Items containing <u>one</u> relevant and <u>one</u> irrelevant cue.

II. <u>One</u> relevant and <u>two</u> irrelevant cues.

III. <u>One</u> relevant and <u>three</u> irrelevant cues.

IV. <u>Two</u> relevant and <u>one</u> irrelevant cue.

V. <u>Two</u> relevant and <u>two</u> irrelevant cues.

The actual items used are presented in Appendix E.

The format of the test proper consisted of showing the child three examples which all contained the relevant cue. The child was instructed that the three pictures were the same in some way and he was to look at them carefully to see in what way they were alike. He was then shown three more pictures and was asked to point to the one which belonged with the previous three. (A set of three positive examples of the concept, together with the three choices constituted an item.)

Prior to the administration of the test proper, <u>S</u> was given

some sample items to insure familiarity with both the task and the cues employed. A correction procedure was used on the sample items, but not on the test proper. This test was administered to all 168 children in the sample.

V. Results

1. Bimodal Reaction Time

Two measures of reaction time were employed in the analysis of the data: (a) mean reaction time to stimuli which were preceded by stimulation in a different modality and (b) mean reaction time to stimuli preceded by same-modality stimuli. These measures will subsequently be referred to as cross-modal and ipsi-modal reaction times, respectively. Both of these conditions occurred with equal frequency. The mean reaction times of each group are presented in Table 2.

Table 2

Mean Reaction Times (in milliseconds)

Group	Type of Reaction Time	
	Ipsi-Modal	Cross-Modal
First Grade-low	772	862
First Grade-high	612	644
Third Grade-low	501	586
Third Grade-high	507	559
Fifth Grade-low	449	491
Fifth Grade-high	397	418

A mixed type III analysis of variance (Lindquist, 1953) was conducted on the scores, which is presented in Appendix F_1. The analysis indicated that, as expected, all Ss took longer to respond to stimuli

which were preceded by a stimulus in a different modality ($F(1,42) = 50.93$, $p<.001$). The main effect of age was statistically significant ($F(1,42) = 14.44$, $p<.001$) indicating that older children have faster overall reaction times. The mean total reaction times for the first, third and fifth grade groups were 726, 541, and 438 msecs., respectively. Although the poor readers responded more slowly, the main effect of reading level was not significant at the generally accepted level ($F(1,42) = 3.87$, $p<.10$).

The result of major interest to the hypothesis initially advanced is the interaction between type of reaction time (i.e., ipsi- and cross-modal) and reading level. This interaction was significant at the .01 level ($F(1,42) = 7.37$) indicating that retarded readers exhibited greater difficulty than normal readers in shifting from one modality to another. The mean increase from the ipsi- to the cross-modal condition for the retarded readers was approximately twice that for the high reader groups. Thus, this interaction supports the hypothesis that poor readers cannot shift attention between modalities as rapidly as normal readers.

Although the difference between good and poor readers was somewhat greater at the earlier age levels, the interaction of age by reading level did not reach the generally accepted level of significance. Neither were the other interaction effects statistically significant.

Since the two reading groups differed with respect to IQ scores, the question can be raised as to whether intellectual factors played a role in the differences in modality shifting behavior. In order to obtain information on this question, difference scores between cross- and ipsi-modal reaction times were computed for each S, and these were correlated

with Lorge-Thorndike IQ scores. The resulting correlation coefficient was -.21 which was not significantly different from zero (Z = 1.46). In addition, the correlation obtained between IQ and total reaction time was not significant (r = .22). Thus, it may be concluded that performance on this bimodal reaction time task is not significantly related to intelligence.

2. Continuous Performance Tests

(a) Visual and Auditory Forms

The number of correct responses was obtained on the auditory and visual form for each S. A correct response was classified as one in which the S pressed the button from 100 msec. to 1 sec. after the onset of a red stimulus. Responses occurring sooner than 100 msec. after stimulus onset were considered to be anticipatory responses, and these were analyzed separately. The upper limit of one sec. was chosen because after that time the succeeding stimulus was automatically presented. The mean percent of correct responses on these tasks is presented in Table 3.

Table 3

Mean Percent of Correct Responses on Continuous Performance Test in Single Modality (N = 11 in each group)

	Modality	
Group	Auditory	Visual
Second-Low	65.0	46.2
Second-High	85.0	50.0
Fourth-Low	77.8	65.5
Fourth-High	88.1	66.5
Sixth-Low	92.6	76.6
Sixth-High	91.8	81.6

An analysis of variance of these scores, presented in Appendix F_2 revealed that the three main effects of age, reading level and modality were all statistically significant. This indicates that older children perform more efficiently ($F(2,60) = 29.93$, $p<.001$), that poorer readers exhibited poorer performance ($F(1,60) = 4.85$, $p<.05$), and that all children did better on the auditory form of this task than on the visual ($F(1,60) = 88.37$, $p<.001$). None of the interactions was statistically significant.

An analysis subsequently conducted on the number of anticipatory responses (See Appendix F_3) revealed trends which paralleled the above analysis. More anticipatory responses were made by younger children ($F(2,60) = 3.98$, $p<.05$), by poorer readers ($F(1,60) = 9.25$, $p<.01$), and with respect to the visual modality ($F(1,60) = 26.76$, $p<.01$). In addition, the reading level by modality interaction was significant ($F(1,60) = 5.68$, $p<.05$) indicating that the differences between the good and poor readers were mostly attributable to performance on the auditory form.

The significant difference between good and poor readers on the number of anticipatory responses is of interest because it shows that the poor readers were responding, i.e., were pressing the button as often as the good readers, but were responding incorrectly.

Correlations obtained between IQ scores and visual CPT performance were not significant. Intelligence scores were, however, related to auditory performance at the second and fourth grade levels ($r = .59$ and $.62$, respectively), but not at the sixth grade ($r = -.27$). In an additional analysis, difference scores between auditory and visual performance were obtained from each S and these were correlated with

Lorge-Thorndike IQ scores. The resultant correlations were not statistically significant at any grade level.

(b) Combined Auditory-Visual Form of the CPT

Correct responses on this technique were defined in the same manner as on the single channel vigilance task. The mean percent correct responses on the combination form are presented in Table 4.

Table 4

Mean Percent Correct Responses
on Combined Auditory-Visual Form of CPT

	Modality		
Group	Auditory	Visual	Total
First-low	80.0	45.5	62.8
First-high	62.7	54.1	58.4
Third-low	83.5	43.4	63.4
Third-high	78.7	75.5	77.1
Fifth-low	87.5	85.9	86.7
Fifth-high	86.5	87.0	86.7

Analysis of these data (See Appendix F_4) showed that poor and good readers did not differ significantly on the overall number of correct responses. The differences between age groups and between modalities were significant at the .01 level, indicating that older children make more correct responses, and that the visual stimuli are most difficult for all Ss. This latter finding corroborates the results obtained with the single channel forms. In addition, the reading level by modality interaction was significant ($F(1,36) = 6.49$, $p < .05$) indicating that the poor readers exhibit a greater discrepancy between auditory and visual vigilance performance than do the good readers.

Some differences in the pattern of results of the single-channel and combination forms of the CPT should be noted. Although visual performance is inferior on all forms of the CPT, performance of the reading groups with respect to the auditory form deserves some comment. On the single-channel auditory form, the second and fourth-grade poor readers performed poorly compared to the normal readers. On the combination form, the auditory performance of the first and third-grade poor readers was somewhat superior to the normal readers. Unfortunately, the age groups on these tasks are not directly comparable. The results do suggest, however, that vigilance performance on two channel tasks may not be predictable from single-channel ones. Apparently, having to attend to auditory and visual stimuli at the same time may require different skills than attending to either modality in isolation.

3. Modality Preference Test

The measure employed in this technique was the average duration of presses made to the auditory and visual stimuli by each child. Analysis of variance of this data revealed tremendous variability and no significant main effects or interactions. Thus, it may be concluded that poor and good readers do not differ in auditory and visual preferences, per se, at least as can be measured by this particular technique.

4. Discrimination Tasks

The mean number of errors made on the various discrimination tests are presented in Table 5. These errors represent the number of times the children responded "same" to the 16 pairs of stimuli in each test which were actually different.

Table 5

Total Number of Errors to Different Pairs on Discrimination Tests

	English		Hebrew	
Group	Auditory	Visual	Auditory	Visual
Second-low	88	91	102	132
Second-high	38	27	50	92
Fourth-low	36	37	59	103
Fourth-high	18	22	39	96
Sixth-low	33	22	53	93
Sixth-high	10	9	20	71
Total	220	208	323	587

Appendix F_5 presents the analysis of variance which was performed on these error scores. This analysis indicates that the main effects of age and of reading level, and the age by reading level interaction were statistically significant. These differences are in the expected direction, i.e., older children and good readers exhibit better discrimination skills than do younger children and poor readers. The significant interaction indicates that discrimination skills differentiate best between the younger good and poor readers, at the second grade level.

The effect of modality and meaningfulness were also statistically significant at the .001 level. Thus, not surprisingly, all children perform better on the English than on the Hebrew word pairs. Overall performance was poorer with the visual stimuli than it was with the auditory. The difference in modality, however, seemed mostly attributable to the difficulty the children had with the Hebrew visual stimuli. This

was corroborated by the significant modality by meaningfulness interaction which indicated that when non-meaningful stimuli were employed, visual performance was poorer, whereas with familiar English words, no such difference was evident. Neither modality nor meaningfulness interacted with age or reading level, thus suggesting that the underlying discrimination skill, rather than familiarity with the material is differentiating the groups.

In summary, these findings may be taken as evidence for the fact that poor and good readers differ in their ability to discriminate between pairs of linguistic stimuli presented in two modalities with two degrees of meaningfulness. The differences were most pronounced at the younger age levels.

Intelligence appears to be related to both auditory and visual discrimination at the three grade levels. Pearson product-moment correlations between IQ and number of auditory errors for the second, fourth and sixth grades were: -.53, -.61, and -.40, respectively; corresponding correlation coefficients involving visual discrimination errors and IQ were: -.68, -.39 and -.56. All were statistically significant. Thus, it may be concluded that discrimination performance is related to age, reading ability and Lorge-Thorndike scores.

5. Memory Span

Digits

On the digit span tests, the measure employed was the maximum number of digits the child could repeat correctly. Table 6 presents the mean correct responses for each group.

Table 6

Mean Correct Responses on Digit Span

	Modality		
Group	Auditory	Visual	Total
First-low	4.0	1.4	2.7
First-high	4.5	3.4	4.0
Third-low	4.1	3.6	3.8
Third-high	5.4	4.6	5.0
Fifth-low	5.2	4.6	4.9
Fifth-high	5.2	5.4	5.3

An analysis performed on this measure presented in Appendix F_6 revealed that the main effects of age, reading level, and modality were all statistically significant at the .001 level. Thus, the older children and the good readers remember more and, in general, better performance is evident on the auditory form. A significant age by modality interaction ($F(2,42) = 7.69$, $p<.01$) revealed that the younger children have their greatest difficulty with visually-presented digits. It should be noted, however, that this finding may be somewhat of an artifact since some of the first-grade children were rather inaccurate in being able to read visual digits. This was somewhat surprising since pretesting with a similar group of Gs had revealed that they had been able to understand visually presented numbers. In view of this, therefore, these findings should be accepted with caution.

Correlations between digit span (auditory and visual) and IQ were performed at each grade level. The only significant correlation ($r = .48$, $p<.05$) was found between visual digit span and IQ on the third grade level. All the others did not reach the generally accepted levels

of confidence. The general absence of relationship was somewhat surprising since the Digit Span is actually used as a subtest of the Wechsler Intelligence Scale for Children. The Lorge-Thorndike Test, however, contains tasks of a different nature which do not involve immediate memory.

Verbal Material

The mean number of correct responses made by the various groups are presented in Table 7.

Table 7

Mean Number of Correct Responses on Word and Picture Memory Span (Maximum = 8)

	Modality		
Group	Auditory	Visual	Combined Auditory & Visual
First-low	3.4	3.4	3.4
First-high	3.9	4.4	4.2
Third-low	2.6	4.1	4.2
Third-high	3.8	4.2	4.2
Fifth-low	2.8	4.0	4.2
Fifth-high	4.0	4.1	5.1
Total	3.4	4.0	4.2

An analysis of variance on these scores revealed that the effects of reading level and modality were statistically significant at the .01 level (See Appendix F_8 for this analysis). Thus, on memory for verbal material, poor readers have shorter memory spans than do good readers. Additionally, all children exhibit poorest performance on auditorially-presented stimuli. Interestingly enough, no age differences

were noted on this task.

6. Serial Learning

The primary measure employed in analyzing the children's serial learning was the total number of correct repetitions made by S in fifteen trials of an eight-item test. It should be recalled that three forms of serial learning were administered: an auditory, a visual and a combined auditory-visual presentation. The mean number correct on each of these forms is presented in Table 8.

Table 8

Mean Number Correct on Serial Learning (Maximum = 120)

	Modality		
Group	Auditory	Visual	Combined Auditory & Visual
First-low	83.2	96.9	78.0
First-high	109.5	106.8	110.6
Third-low	94.1	105.1	100.6
Third-high	108.4	112.0	113.2
Fifth-low	102.5	111.0	109.4
Fifth-high	109.0	110.4	116.1
Total	101.2	107.0	104.0

The analysis of this measure, presented in Appendix F_8 revealed significant differences associated with age, reading level and type of presentation. Older children learned more easily than did young children and good readers showed better learning scores than did poor readers. For the sample as a whole, visual presentation was easiest, whereas the auditory modality evoked the greatest difficulty. The one exception to

this occurred in the first-grade potentially poor reader group which had the lowest scores on the combination form.

As was true with the discrimination skills, the interaction between age and reading level was significant, indicating that this task differentiates reading level best with younger children.

The finding which is perhaps of greatest interest is the significant reading level by modality interaction ($F(2,84) = 7.08$, $p<.01$). This indicates that although the poor readers learned more slowly on all tasks, they had particular difficulty with auditory stimuli. The average discrepancy between the auditory and visual forms was 10.9 for the retarded group as compared with .7 for the normal readers. Thus, the poorer readers exhibited a more uneven pattern of modality functioning.

Inspection of the data revealed that, contrary to expectation, the retarded readers gave as many verbal responses as did the good readers. Many of these responses, however, were extraneous and appeared to represent associations to the stimulus material such as substituting the response "spoon" for the stimulus "cup" or "cat" for "dog". The mean number of such associational responses for the retarded and normal groups was 10.0 and 2.9 respectively. This difference was statistically significant at the .05 level ($F(1,42) = 4.17$). Furthermore, there was a greater tendency for such association errors to occur under conditions of auditory presentation. In the total sample, the average number of extraneous responses was 10.5 on the auditory form as compared with 2.5 on the visual, a difference significant at the .01 level ($F(1,42) = 8.06$). This finding thus corroborates the results presented above indicating that children have their greatest difficulty focusing on auditory stimuli in serial learning.

Once again the question may be raised concerning the role of intelligence. The correlation between composite learning score (all serial learning tasks) and IQ was statistically significant in the first-grade group ($r = .56$), but not significant on the third or fifth grade level. Correlations obtained between auditory-visual discrepancy scores and IQ were not significant. Thus, it may be concluded that IQ is related to learning performance only at the first-grade level.

7. Concept Formation Test

This test was administered to all 168 children in the total sample. Because several internal variables were of interest in terms of developmental differences, a variety of test scores were analyzed in several different ways.

The first and most straightforward analysis was performed on the total number of correct responses. This analysis, presented in Appendix F_3 revealed the overall effect of reading level and age to be significant at the .01 level. The interaction of age by reading level was not significant, indicating that this Concept Formation Test differentiates reading level equally well with the three age groups under investigation.

The two variables of theoretical interest relative to previous work done with adults were the amount of irrelevant information and the type of relevant stimulus cue. The effect of the correct stimulus cue in the first twelve items, i.e., either form, color, size, or number, is illustrated in Table 9.

Table 9

Number Correct on Differing Stimulus Cues on Concept Formation Test

	Cue			
Group	Form	Color	Size	Number
First-low	53	45	44	49
First-high	46	54	52	58
Third-low	52	53	55	48
Third-high	59	51	61	63
Fifth-low	66	66	55	54
Fifth-high	59	58	60	68

Analysis of these data revealed that the effect of stimulus cue was not statistically significant, nor did it interact significantly with other variables (See Appendix F_{10} for the analysis). This finding is in accordance with Archer and Bourne's results with adults. It is contradictory, however, to other work with children (e.g., Kagan, 1962). One possible explanation for the discrepancy is that the method employed in the present investigation was adapted from Archer and Bourne and not Kagan's, and the conceptual tasks differed somewhat.

The effect of irrelevant stimulus information was investigated with two measures, number correct, and latency. Both of these measures reflected item difficulty in adults.

The total number of correct responses made by each group for each of the five categories of the test is presented in Table 10.

Table 10

Mean Number Correct in each Category of Concept Formation Test

	Category				
Group	I One Rel. Cue One Irrel. Cue	II One Rel. Two Irrel.	III One Rel. Three Irrel.	IV Two Rel. One Irrel.	V Two Rel Two Irre
First-low	3.10	2.18	1.49	2.48	2.15
First-high	3.40	2.47	1.56	2.91	2.45
Third-low	3.28	2.34	1.79	2.81	2.31
Third-high	3.71	2.78	1.85	3.23	2.57
Fifth-low	3.77	2.99	1.84	3.28	2.55
Fifth-high	3.73	2.79	1.92	3.47	2.86

The analysis based on these scores (See Appendix F_{11}) shows the effect of category to be significant at the .001 level. The trend can be observed in Table 10. Holding the number of relevant cues constant, items become more difficult as more irrelevant information is added. This is in accordance with the results obtained in adult populations, and may be interpreted as indicating that hypotheses in forming concepts become more difficult as distracting stimuli are added.

The results relevant to the latency measures are presented in Table 11.

Table 11

Latency Measures (in seconds) on each Category of Concept Formation Test

Group	Category I One Rel. Cue One Irrel. Cue	II One Rel. Two Irrel.	III One Rel. Three Irrel.	IV Two Rel. One Irrel.	V Two Rel Two Irre
First-low	36.9	34.7	26.6	22.3	24.3
First-high	35.9	39.1	30.4	25.4	25.4
Third-low	28.6	34.4	34.1	26.8	29.0
Third-high	26.0	33.5	31.9	21.3	27.5
Fifth-low	31.8	39.4	30.5	22.3	23.1
Fifth-high	22.4	37.1	34.9	21.3	26.8

The effect of category is significant at the .001 level. (See Appendix f_{12}). Thus, differing amounts of stimulus information are related to the time to solution on children's concept formation. It can be noted that the pattern of latency measures is not as clear-cut as was the number correct measure. This may be partially explained by the significant age by category interaction which was obtained. It would appear that the fifth grade children's performance more closely approximate that of adults, i.e., additional cues tend to increase the time required to make a response. The performance of the first grade children, on the other hand, exhibits a different pattern. The younger children display the longest latency at the beginning and get faster with additional information. One possible explanation for this difference may be that as the item becomes more difficult, the younger group is responding in a more or less random fashion, perhaps not attending to the specific aspects of the problem. This is partially reflected in the number of errors made.

In any event, more work is needed in this area to elucidate developmental trends.

Another question which may be raised with respect to concept formation ability concerns its relationship with intelligence. Accordingly, correlations were run between Lorge-Thorndike IQ's and concept formation scores for each grade level. The Pearson product-moment correlations for the first, third and fifth grades were .28, .20, and .14, respectively. Only the correlation obtained with first grade Ss was significantly different from zero at the .05 level, and it should be noted that the obtained correlation of .28 is exceedingly low for predictive purposes. Thus, it may be concluded that although performance on this perceptually-oriented concept formation task is related to age and reading level, it is not very strongly related to IQ. It might be expected that a concept formation task which was more heavily loaded with verbal factors would show a correspondingly higher relationship to intelligence test scores.

VI. Conclusions and Implications

Possibly the most significant finding emerging from this project was that practically all of the auditory and visual skills tapped differentiated good from poor readers. Since many of these techniques have a long psychological history, the results of this study will first be discussed individually in the light of previous work done in the area.

On what might be considered the least complex of the response measures used, poor readers exhibited greater difficulty in switching from one modality to another than did good readers of the same chronological age. This result suggests that one variable which may

underlie reading performance is the capacity to respond quickly to two sequentially presented stimulus modalities. This finding is in accordance with the earlier study of Raab, Deutsch and Freedman which also found such differences. In the present investigation, however, the trend was observed in younger children as well as older ones.

In general, children retarded in reading revealed poorer performance in vigilance situations. The low reading group made fewer correct responses and more incorrect responses, thus suggesting a deficiency in their capacity to sustain attention to a specific stimulus. This deficiency was especially pronounced on visually-presented stimuli. One possible reason for this finding may be that the visual stimuli, which were dots of color, were more similar to one another than the color names. (It should, of course, be noted that none of the Ss were color-blind.) Results on the combined auditory-visual presentation revealed another trend. Here, it was noted that poor readers had greater discrepancies between auditory and visual performance. Some of the younger poor readers, in fact, got all responses correct in one modality while ignoring the other completely. This finding may be interpreted as corroborating the results on the Bimodal Reaction Time apparatus, i.e., that poorer readers experience difficulty responding appropriately to two stimulus modalities at the same time. It should be noted that these interpretations cannot be adequately verified at the present time, since no previous work has been done relating vigilance performance to reading achievement. The findings of this study, however, suggest that this may be a fruitful area for investigation.

Performance on the Modality Preference Test was the only variable

in the present study found to be unrelated to reading ability. One explanation of this result is that preference, per se, is simply not a factor in reading. Another alternative, of course, is that the technique employed here was not a very good measure of modality preference. Once again, however, it is difficult to evaluate this finding, because of the lack of any previous investigations.

The results on the discrimination tasks may be taken as corroboration for the positive findings obtained in the previously cited studies. Poor readers differed from good readers in both auditory and visual discriminati It was noted that the presentation of auditory and visual stimuli was better controlled in the present study than in the earlier ones. Furthermore, the present investigation included two levels of meaningfulness. Thus it was possible to determine that although meaningfulness affected discrimination generally, it did not interact with reading level. Differences in the performance of good and poor readers were due to discrimination skill variability and not to increased familiarity with the stimuli.

On the more complex tasks, the good readers exhibited longer memory spans, superior learning efficiency and a significantly better capacity to form concepts. These general findings are in accordance with results previously reported and reviewed (Johnson, 1957). An interesting discrepancy between the present findings and those of earlier studies occurred with respect to the memory and learning of words. On these tasks, the auditory presentation of stimuli appeared to elicit poorer performance. Furthermore, this was especially pronounced in retarded readers as evidenced by the significant reading level by modality interaction. The earlier investigations of children's auditory and visual learning reported

that auditory presentation was superior in children. One difficulty, however, of these earlier studies was that the visual stimuli were printed words. Thus, the visual presentation differed from the auditory not only in modality, but also in familiarity for the young children. One possible reason for the different results obtained in this study is that the visual stimuli were pictures of objects which were familiar to all the children. Under such conditions it would appear that visual presentation elicits better performance.

Investigation of developmental trends in the present study revealed that age differences paralleled the differences in reading achievement. This suggests that good readers may be operating on a higher developmental level perceptually, than their retarded reader counterparts. Overall age differences were obtained on reaction times, vigilance performance, discrimination skills, digit span, serial learning and concept formation. Only the memory for words task failed to differentiate among first, third and fifth grade children. Why this should be the case is somewhat puzzling There did not seem to be very much variability on this measure so that it is possible that the age range was restricted with respect to word memory. It may be that if older children were included, developmental trends might be observed.

The question can be raised of the differences in perceptual development for poor and good readers. With regard to this issue, it is of interest to note that certain of the measures differentiated good and poor readers equally well at all age levels studied whereas others discriminated children of differing reading ability best at the younger age levels. Reaction time to shifting modalities, vigilance performance and capacity to form concepts significantly differentiated good and

retarded readers at the fifth and sixth as well as at the first and second grades. On the other hand, significant age by reading level interactions were obtained in discrimination and serial learning performance. This suggests that there are some skills in which poor readers "catch up" developmentally, whereas there are others in which they continue to function at a lower level. It is of course impossible to say whether this "catching up" is mainly due to maturational or experiential variables, since these were not controlled for in the present study. Future study of the determinants of this pattern might yield some valuable information.

The direction of the age by reading level interactions which were obtained deserves some comment. The fact that the differences between the potentially good and poor readers at the first grade were greater than with the older children on some tasks lends support to the notion that perceptual factors may play a causative role in producing reading retardation.

Since one of the primary interests of the present investigation was the study of modality functioning in children, the obtained patterns of performance with respect to the auditory and visual modalities warrant some discussion. It is evident from the findings that children are not equally proficient with regard to both auditorially and visually presented stimuli in all the perceptual skills investigated herein. The actual patterning of modality functioning appears to be a complex issue. Children's visual performance was inferior on tasks involving vigilance, discrimination and memory for digits. The reverse was true for memory and serial learning of words where a distinct disadvantage was evident on auditorially-presented stimuli. If the responses sampled herein can

be taken to reflect an underlying continuum of complexity, ranging from simple button pressing to the learning of meaningful material, then the possibility suggests itself that auditory stimulation creates greater difficulties for children as the task becomes increasingly complex and meaningful. Further study is indicated to substantiate this supposition.

Although differences were observed between the auditory and visual functioning of all children on a few of the tasks (e.g., vigilance and serial learning), significant reading level by modality interactions were obtained on others, thus suggesting that with poor readers, the discrepancy in modality functioning is even greater than that which would be normally expected. This more uneven pattern of performance by the retarded readers revealed itself not only with respect to the single-channel tasks, but on those requiring attention to both modalities as well. Since the fifth and sixth grade children tended to show the least discrepancy between modalities, it is possible that the poor readers' performance is indicative of a developmental lag in perceptual functioning. It would be useful in this regard, to obtain similar data from adults.

The relationship of intelligence test scores to the tasks employed in the present study deserves somecomment. Since it has so frequently been demonstrated that standardized IQ scores of various kinds are related to scholastic achievement, educators may at times tend to "explain" any differences obtained between high and low achievers as a function of IQ. The present investigators do not, of course, take the position that the intellectual status as measured by IQ tests does not play a rather obvious role in learning how to read. The correlations obtained, however, between reading performance and IQ scores typically range from .50 to .60

(Johnson, 1957). When these figures are viewed as a problem in statistical prediction, knowing IQ scores of children still leaves a great deal of the variability in reading skills unaccounted for (i.e., from 64% to 75%, to be specific). Thus, there are clearly other factors besides intelligence which contribute to achievement in reading. Many of the skills measured in the present study such as modality shifting, vigilance, digit span, serial learning and concept formation were shown to be significantly related to reading ability and not primarily to IQ scores. It should be noted that the primary concern of the present study was not to ferret out the intellective and nonintellective components underlying reading skill. This is a complex problem worthy of study in its own right and one which would require a different kind of experimental design, i.e., one using partial correlational techniques. The results of the present study, however, do suggest that many perceptual measures may contribute to the prediction of reading achievement in a way that does not overlap with intelligence test scores.

Pragmatically, the findings of the present study suggest that what is needed is both more careful and detailed analysis of the various skills involved in reading than has been done heretofore, plus a better assessment of children's functioning with regard to these skills. Such an analysis should be undertaken with a view towards developing more precise and experimentally-determined teaching techniques which might hopefully counteract the varied deficiencies children bring with them to the classroom.

In order to do this most effectively, the educator would, of course, need to obtain information about a child's perceptual skills. It is

interesting to note that although a great deal of attention has been devoted to the measurement of intellectual factors in children, not enough practical consideration has been given to the perceptual factors which may underlie reading performance. Thus, although early assessments of children's capabilities usually include intelligence tests, they do not typically include measurement of reaction time or attention. The findings in the present investigation that many perceptual measures were related to reading ability, but were not highly related to standardized IQ scores suggests that nonintellective factors contribute independently towards the prediction of reading achievement. Thus, such perceptual measures might profitably be obtained from children entering school in order to arrive at more accurate diagnosis and remediation of potential scholastic problems.

One final word of caution should perhaps be interjected at this point concerning the present findings. It should be noted that these results were obtained on what might be considered a homogeneous group of children. They were all Negro males and tended, as a group, to fall into the lower socioeconomic stratum, as measured by parental occupation and education. This fact certainly limits the generalizability of the findings to "average" middle-class white children and future investigations should be performed to extend the sample. Pragmatically, however, the present urban sample is one which produces an exceedingly high percentage of scholastic failure. Thus, while the results may not hold true for all children, they can be generalized to the group who may benefit most from improved teaching techniques.

VII. Summary

The most salient findings of the present study may be summarized as follows:

1. Reading, as a complex skill, may be adversely affected by any one of several basic psychological processes. The latter include attention discrimination, memory and learning, and conception.

Within the attentional area, poor reading is associated with (a) difficulties in shifting from one sensory mode to another, as well as (b) difficulties in inhibiting reaction to inappropriate stimulation.

With respect to discrimination, poor readers have a general difficulty in differentiating between similar stimuli whether the latter are presented auditorially or visually, and whether the stimuli comprise more or less meaningful figures.

With regard to memory and learning, the poor readers recall and learn sequentially presented material less efficiently than the more skillful readers.

2. Difficulties in attending, memorizing, or learning within particular sensory modes are related to reading retardation. Thus, poor readers are especially prone to show attentional lapses when confronted by simple visual as compared to simple auditory stimuli.

On the other hand, when the task is more complex and memory or learning is involved, the poor reader shows the greatest difficulty in handling auditory rather than visual material.

3. The reading level of younger children is particularly affected by difficulties in discrimination and learning. Thus it is mainly among the younger children that the poor readers show special difficulty in

sensing the fine differentiations between perceptually-similar pairs of stimuli. Similarly, it is among the younger children that the learning difficulty is associated with lowered reading scores.

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A. Reading Prognosis Test
Examiner's Record Book

1. Naming Letters

d m e y r t l h c s

q n b v j w e x p f

k z i o g u

Total Score_____

A G O I Z K F P S E

W J V L C B Q D U R

N X H T Y M

Total Score_____

2. Meaning Vocabulary

orange
knife
donkey
bench
puddle
diamond
sword
double
nuisance
scorch
hero
microscope
lecture
skill
fable

Total Score_____

3. Sight Vocabulary

look	come	play	baby	my	
mother	boy	school	five	today	Total Score_____
NO	BUS	WALK	MILK	STORE	
EXIT	ONE-WAY	ICE CREAM	MOVIE	COCA COLA	Total Score_____

4 & 5. Child's Test forms of Visual Discrimination and Visual Similarities are attached.

Visual Discrimination
Total Score_____

Visual Similarities
Total Score_____

6. Auditory Discrimination

tub	sit	tall	pen	train	good	there
tug	set	talk	pen	track	look	were
when	rob	rat	duck	doll	nice	open
hen	rub	fat	buck	ball	nice	upon

stocking	expression	contribution	remarkable
socking	expansion	constitution	markable

Total Score_____

7. Story Telling - Copy child's story below and on reverse side.

VISUAL DISCRIMINATION

c	c
c	e

u	u
u	v

r	n
r	r

p	p
q	p

m	w
w	w

pan	pan
pen	pan

cat	cat
cat	oat

duck	buck
duck	duck

box	pox
pox	pox

tat	tat
fat	tat

crook	crock
crook	crook

mouth	mouse
mouth	mouth

blind	blimp
blind	blind

moton	moton
motor	moton

women	women
women	woman

torque	tongue
tongue	tongue

radial	radicl
radial	radial

VISUAL SIMILARITIES

f g
h
h l

a l
a
v s

a o
c
c e

d p
b
q b

v n
n
u r

look good
book
food book

run nun
run
rur ran

dab dad
bad
bad bab

tee tea
tea
ate eat

warm warn
worn
worn worm

lamb lamp
lamb
lamd lamq

plar plan
plan
glan plam

ribbon ribden
ribbon
ridbon riddon

spot stop
stop
pots tops

great grect
greet
greet greot

cook cock
cock
coak cack

hurny hurry
hurry
hunny harny

B. Stimulus Program Used on Bimodal Reaction Time Apparatus

Key: R = red
G = green
H = high
L = low

BLOCK

1	2	3	4	5	6
G	L	H	R	G	L
L	H	R	G	L	H
H	H	G	G	H	H
H	G	G	H	H	G
G	R	H	L	G	R
G	G	H	H	G	G
R	L	L	R	R	L
H	L	G	R	H	L
R	R	L	L	R	R
L	H	R	G	L	H
L	L	R	R	L	L
G	G	H	H	G	G
H	G	G	H	H	G
L	H	R	G	L	H
R	R	L	L	R	R
R	R	L	L	R	R
R	R	L	L	R	R
G	H	G	R	G	L
H	H	G	G	H	H
R	G	L	G	H	G
L	L	R	R	L	R
G	G	H	H	G	G
R	G	H	L	G	H
H	G	H	G	H	G
G	H	R	H	G	R
G	H	L	G	G	H
L	L	H	H	L	L
H	L	G	G	L	R
L	R	L	R	R	R
R	R	L	L	R	R
R	G	L	H	G	L

C. Stimuli Employed in Discrimination Tasks

English Word Pairs

Auditory	Visual
moon - noon	car - cat
lack - lack	rah - ran
lease - leash	met - wet
coast - toast	leg - leg
leg - led	hot - not
king - king	but - but
badge - badge	fog - tog
cat - cap	oil - ail
chap - chap	map - nap
shack - sack	our - our
sheaf - sheath	oft - off
thimble - symbol	fun - fun
sought - fought	and - and
wretch - wretch	ran - tan
gum - dumb	bin - din
shake - shape	rob - nob
dim - din	hem - hew
pose - pose	car - can
bale - gale	say - say
muff - muss	ram - ran
thread - shred	cab - cad
web - wed	pet - pet
jam - jam	boo - boa
zest - rest	dog - dog

Hebrew Word Pairs

Auditory

morb - morb

sef - seth

vom - von

luff - luff

rabor - rabor

shub - shud

shabat - shabak

fol - thol

mod - mog

baf - gaf

arretz - arretz

shen - sen

kelay - telay

omair - omair

make - make

mort - nort

tayeem - payeem

gerdol - derdol

lotz - lotz

lith - liss

neek - neep

zov - zov

sidg - thidg

yib - yig

D. Stimuli Employed in Memory Span and Serial Learning

List A (Auditory or Visual)	List B (Auditory or Visual)	List C (Combined Auditory-Visual presentation)
Ball	Cup	Bear
Fish	Nail	Key
Hat	Eye	Girl
Clock	Chair	Bus
Dog	Train	Star
Dress	Flag	Door
Shoe	Comb	Car
Clown	Bell	Drum

E. Schematic Representation of Concept Formation Test

Category	Item	Examples			Choices		
I	1.	triangle - small, red	triangle - small, blue	triangle- small, yellow	square - small, blue	circle - small, red	triangle small, yellow
	2.	red - small circle	red - small triangle	red - small square	yellow - small triangle	red - small circle	blue - small square
	3.	large blue circle	large blue triangle	large blue square	large red square	small red triangle	small red circle
	4.	2 small yellow triangles	2 small yellow circles	2 small yellow squares	1 small red triangle	3 small blue squares	2 small red circles
II	1.	small blue square	medium blue triangle	large blue circle	small blue triangle	large red square	medium yellow circle
	2.	2 red triangles	1 yellow triangle	3 blue triangles	2 yellow circles	3 red squares	1 blue triangle
	3.	small red triangle	small blue circle	small yellow square	large red circle	small yellow triangle	large blue square
	4.	large blue triangle & small blue circle	large blue square & large blue circle	small blue triangle & small blue circle	large red circle & small red square	small red triangle	large red triangle & small red circle & square

Category	Item	Examples			Choices		
III	1.	small yellow circle	large yellow triangle; small yellow circle; large yellow square	small yellow triangle; large yellow circle	medium red triangle; medium red circle	medium yellow square	large blue circle & square; small blue triangle
	2.	large blue & small yellow squares	red small & medium squares; large yellow square	medium blue square	medium blue triangle	small & medium red circles; large yellow triangle	small red & blue squares
	3.	1 medium yellow circle	1 small blue triangle	1 large red square	small red square & large yellow circle	1 medium red triangle	small blue triangle & circle
	4.	1 medium yellow circle	medium red square & triangle	medium blue triangle	small blue circle & large red triangle	medium yellow square	large blue square
IV.	1.	medium red triangle	large red triangle	small red triangle	medium red circle	small red triangle	medium blue triangle
	2.	small blue triangle	small blue circle	small blue square	small red triangle	large blue triangle	small blue triangle
	3.	medium yellow triangle & circle	medium yellow square & triangle	medium yellow circle & square	large red triangle; medium red square	medium blue square, circle & triangle	medium red circle & triangle
	4.	2 small red circles	3 small red circles	1 small red circle	2 small red circles	1 large red circle	1 small red triangle

Category	Item	Examples			Choices		
V	1.	blue small circle & blue medium triangle	blue large square & circle	2 small blue triangles	large blue square	small red circle & triangle	large blue circle & small blue circle
	2.	red small & medium triangles	large red triangle	red medium large & small triangles	medium red circle	large & small red triangles	yellow medium & 2 small triangles
	3.	1 medium yellow triangle	2 medium red triangles; 1 medium blue triangle	medium blue & yellow triangles	medium yellow square; medium red circle	medium yellow triangle	small blue triangle
	4.	small red triangle & small blue circle	small yellow square & triangle	small blue & red circles	small yellow circle & red square	medium blue circle & small red square	small yellow square

F_1. Analysis of Variance:
Bimodal Reaction Times

Source	df	SS	mS	F	P
Between Ss	47	14,278,817			
Age	2	5,288,523	2,649,262	14.44	<.01
Reading level	1	710,016	710,016	3.87	NS
Age x Reading level	2	566,540	283,270	1.54	NS
Error (b)	42	7,703,738	183,422		
Within Ss	48	535,613			
Modality	1	259,418	259,418	50.93	.001
Age x. Modality	2	19,384	9,692	1.90	NS
Reading level x Modality	1	37,562	37,562	7.37	<.01
Age x Reading level x Modality	2	5,172	2,586	<1	NS
Error (w)	42	213,977	5,094		
Total	95	14,814,430			

F_2. Analysis of Variance:
Single-channel Continuous Performance Tests -
Number of Correct Responses

Source	df	SS	MS	F	p
Between Ss	65	18,951			
Age	2	8,979	4,490	29.93	<.001
Reading level	1	728	728	4.85	<.05
Age x reading level	2	214	107	<1	NS
Error (b)	60	9,030	150		
Within Ss	66	12,640			
Modality	1	6,982	6,982	88.37	<.001
Age x Modality	2	474	237	3.00	NS
Reading level x Modality	1	132	132	1.67	NS
Age x Reading level x Modality	2	318	159	2.01	NS
Error (w)	60	4,734	79		
Total	131	31,591			

F3. Analysis of Variance:
Single-channel Continuous Performance Tests -
Number of Anticipatory Responses

Source	df	SS	mS	F	p
Between Ss	65	3,083			
Age	2	318	159	3.98	<.05
Reading level	1	370	370	9.25	<.01
Age x reading level	2	15	8	<1	NS
Error (b)	60	2,380	40		
Within Ss	66	2,339			
Modality	1	669	669	26.76	<.001
Reading level x Modality	1	142	142	5.68	<.05
Age x Modality	2	42	21	<1	NS
Age x Reading level x Modality	2	6	3	<1	NS
Error (w)	60	1,480	25		
Total	131	5,422			

F4. Analysis of Variance:
Combined Auditory-Visual Continuous Performance Test -
Number of Correct Responses

Source	df	SS	mS	F	P
Between Ss	47				
Age	2	1,117,237	558,668	11.10	<.01
Reading level	1	22,605	22,605	<1	NS
Reading level x Age	2	141,134	70,567	1.40	NS
Error (b)	42	2,138,822	50,294		
Within Ss	48	3,065,312			
Modality	1	511,647	511,647	11.27	<.01
Age x Modality	2	237,266	118,633	2.61	NS
Reading level x Modality	1	282,404	282,404	6.22	<.05
Age x Reading level x Modality	2	125,892	62,946	1.39	NS
Error (w)	42	1,908,103	45,430		
Total	95	6,485,111			

F5. Analysis of Variance:
Discrimination Tasks - Number of Errors

Source	df	SS	mS	F	p
Between Ss	71	1765.22			
Age	2	518.69	259.34	25.15	<.001
Reading level	1	442.53	442.53	42.92	<.001
Age x reading level	2	123.27	61.64	5.98	<.05
Error (b)	66	680.73	10.31		
Within Ss	216	2319.75			
Modality	1	215.28	215.28	43.23	<.001
Meaningfulness	1	796.67	796.67	159.97	<.001
Modality x Meaningfulness	1	240.28	270.28	54.27	<.001
Modality x Age	2	9.44	4.72	<1	NS
Modality x Reading level	1	4.26	4.26	<1	NS
Modality x Age x Reading level	2	3.04	1.52	<1	NS
Meaningfulness x Age	2	14.26	7.13	1.43	NS
Meaningfulness x Reading level	1	.28	.28	<1	NS
Meaningfulness x Age x Reading level	2	8.89	4.44	<1	NS
Meaningfulness x Modality x Reading level	1	4.75	4.75	<1	NS
Meaningfulness x Modality x Age	2	2.89	1.44	<1	NS
Age x Reading level x Modality x Meaningfulness	2	3.36	1.68	<1	NS
Error (w)	198	986.35	4.98		
Total	287	4084.97			

F_6. Analysis of Variance:
Digit Span - Number Correct

Source	df	SS	mS	F	p
Between Ss	47	132			
Age	2	54	27	21.09	<.001
Reading level	1	20	20	15.62	<.001
Age x Reading level	2	4	2	1.56	NS
Error (b)	42	54	1.28		
Within Ss	48	70			
Modality	1	20	20	25.64	<.001
Age x Modality	2	12	6	7.69	<.01
Reading level x Modality	1	3	3	3.84	NS
Age x Reading level x Modality	2	2	1	2.56	NS
Error (w)	42	33	.78		
Total	95	202			

Fy. Analysis of Variance:
Memory for Words and Pictures -
Number Correct

Source	df	SS	mS	F	p
Between Ss	47	92			
Age	2	1	.5	<1	NS
Reading level	1	15	15.0	8.33	<.01
Age x Reading level	2	2	1.0	<1	NS
Error (b)	42	74	1.8		
Within Ss	96	175			
Modality	2	19	8.5	4.72	<.01
Age x Modality	4	7	1.8	1.00	NS
Reading level x Modality	2	1	.5	<1	NS
Age x Reading level x Modality	4	1	.2	<1	NS
Error (w)	84	147	1.8		
Total	143	267			

F_8. Analysis of Variance:
Serial Learning - Number Correct

Source	df	SS	mS	F	p
Between Ss	47	20,635.66			
Age	2	3,822.42	1911.21	9.34	<.01
Reading level	1	5,993.34	5993.34	29.29	<.001
Age x Reading level	2	2,224.78	1112.39	5.44	<.05
Error (b)	42	8,595.12	204.64		
Within Ss	96	9,110.67			
Presentation	2	826.77	413.38	5.58	<.05
Age x Presentation	4	603.95	150.99	2.04	NS
Reading level x Presentation	2	1,048.18	524.09	7.08	<.01
Age x Reading level x Presentation	4	409.51	102.38	1.38	NS
Error (w)	84	6,222.26	74.07		
Total	143	29,746.33			

F9. Analysis of Variance:
Concept Formation Test - Total Correct

Source	df	SS	mS	F	p
Age	2	163.0	81.5	14.82	<.01
Reading level	1	54.0	54.0	9.82	<.01
Age x Reading level	2	13.0	6.5	1.18	NS
Error	162	892.0	5.5		
Total	167	1022.0			

F_{10}. Analysis of Variance:
Concept Formation Test -
Number correct for each stimulus

Source	df	SS	mS	F	p
Between Ss	167	135.82			
Age	2	12.59	6.30	8.61	<.01
Reading level	1	2.26	2.26	3.09	NS
Age x Reading level	2	2.53	1.26	1.73	NS
Error (b)	162	118.44	.73		
Within Ss	504	348.25			
Stimulus	3	.25	.08	<1	NS
Stimulus x Age	6	4.50	.75	1.09	NS
Stimulus x Reading level	3	4.85	1.62	2.36	NS
Stimulus x Age x Reading level	6	3.63	.60	<1	NS
Error (w)	486	335.02	.68		
Total	671	484.07			

F_{11}. Analysis of Variance:
Concept Formation Test -
Number Correct for Each Category

Source	df	SS	mS	F	p
Between Ss	167	184.7			
Age	2	17.3	8.75	8.84	<.01
Reading level	1	3.9	3.90	3.93	<.05
Age x Reading level	2	2.1	2.10	2.12	NS
Error (b)	162	161.4	.99		
Within Ss	336	477.3			
Category	2	263.7	131.85	206.1	<.001
Age x Category	4	.1	.02	<1	NS
Reading level x Category	2	.1	.05	<1	NS
Age x Reading level x Category	2	2.5	1.25	1.96	NS
Error (w)	326	210.9	.64		
Total	503	662.0			

F12. Analysis of Variance:
Concept Formation Test - Latencies

Source	df	SS	mS	F	p
Between Ss	167	114,378.4			
Age	2	185.8	92.90	<1	NS
Reading level	1	124.2	124.20	<1	NS
Age x Reading level	2	913.3	456.65	<1	NS
Error (b)	162	113,155.1	698.49		
Within Ss	672	145,414.6			
Category	4	16,371.5	4,092.88	21.76	<.001
Age x Category	8	5,273.3	659.79	3.51	<.01
Reading level x Category	4	957.8	239.45	1.27	NS
Age x Reading level x Category	4	922.1	115.26	<1	NS
Error (w)	648	121,884.9	188.10		
Total	839	259,793			